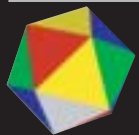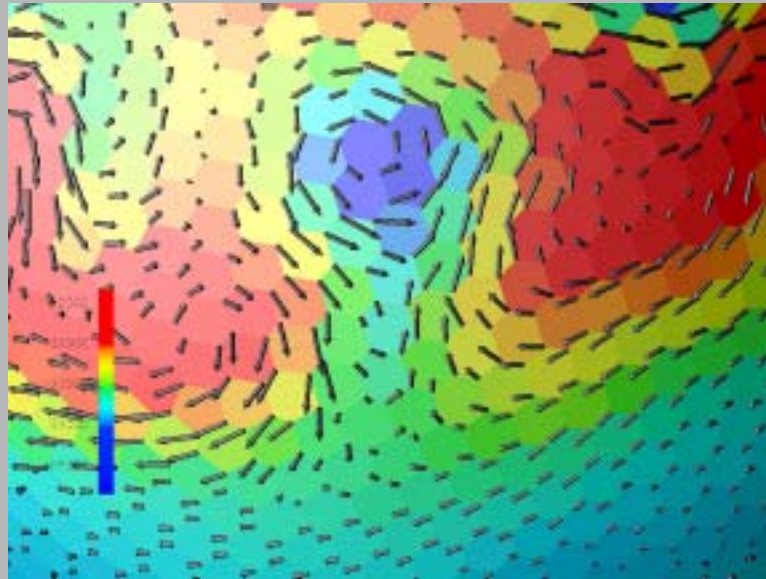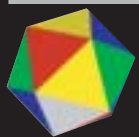# The geodesic climate model of the (near) future

David Randall, CSU
Todd Ringler, CSU
Ross Heikes, CSU
Cara-Lyn Lappen, CSU
Wayne Schubert, CSU
Akio Arakawa, UCLA
Celal Konor, UCLA
Albert Semtner, Jr., NPGS
Don Stark, NPGS
John Baumgardner, LANL
Phil Jones, LANL
Bill Lipscomb, LANL
Scott Fulton, Clarkson University

What's up

We promised to develop and deliver to the Climate Change Prediction Program a *geodesic* coupled ocean-atmosphere-land surface model designed for climate applications.
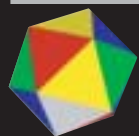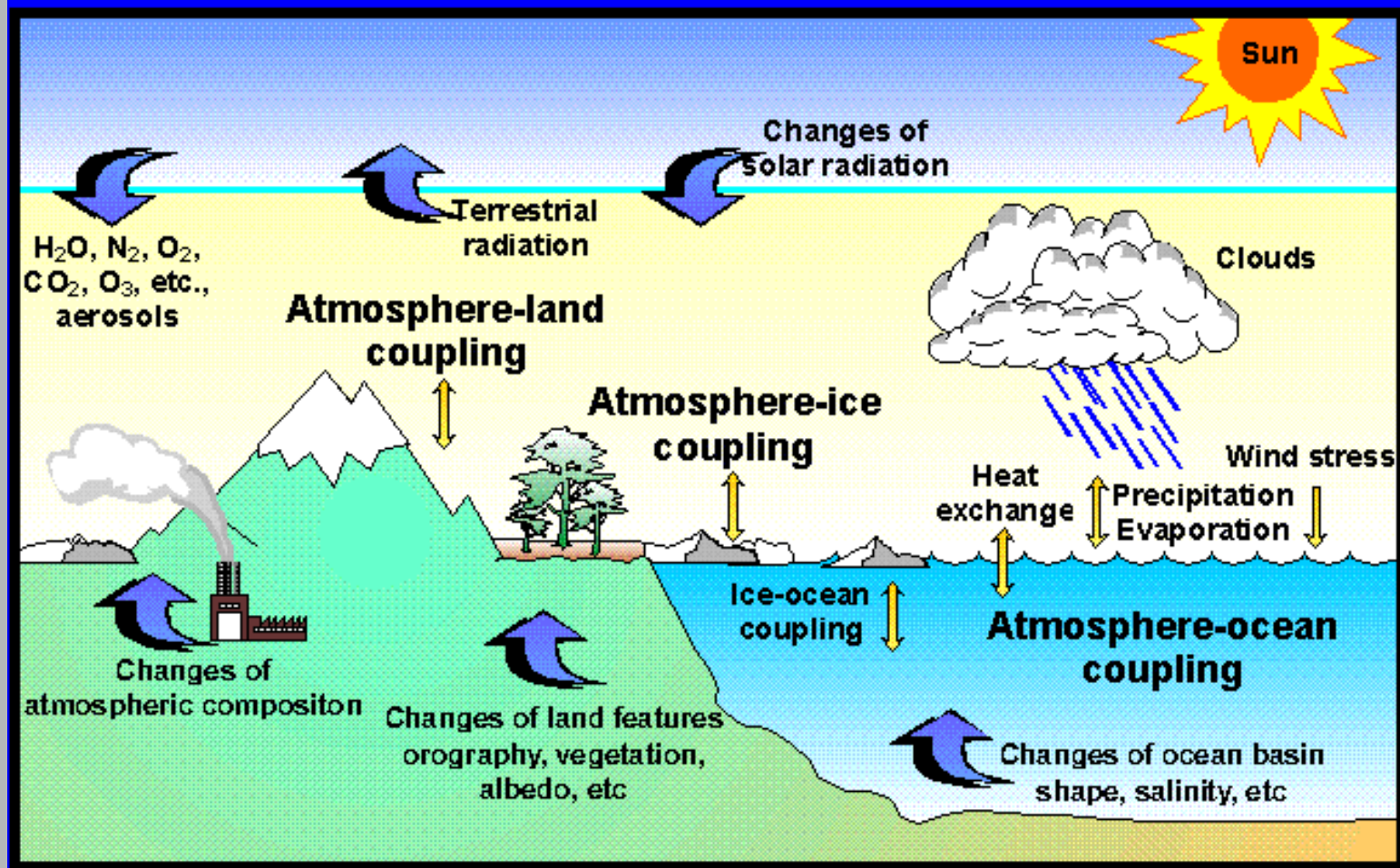
The atmosphere and ocean will use *hybrid quasi-Lagrangian vertical coordinates*.

The computational architecture of the model will be designed for use on *emerging new computer architectures*.
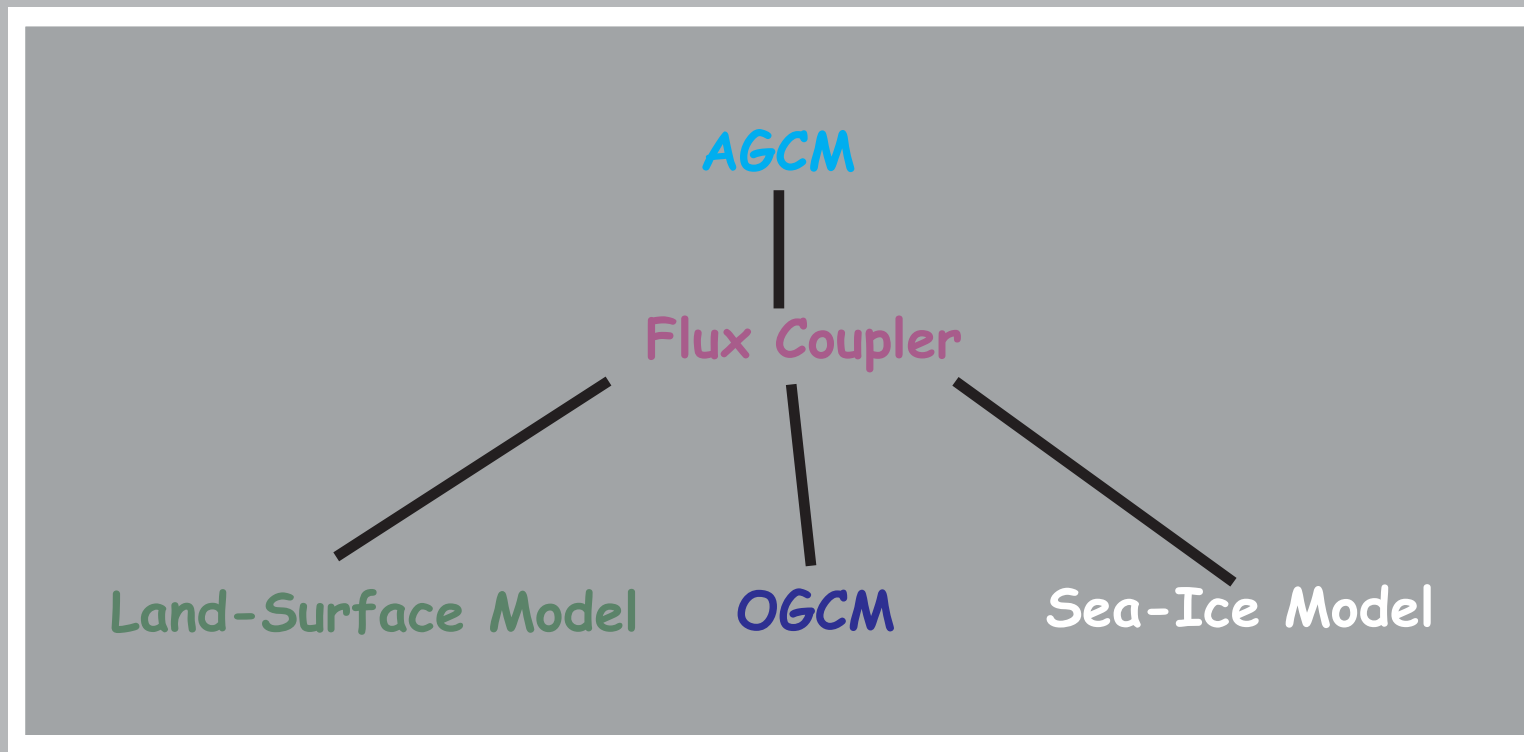
A key goal of our project is to *train young climate modeling researchers* in all aspects of the climate modeling enterprise.
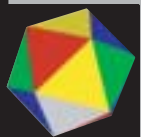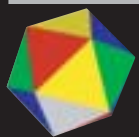
The Climate system

Computational structure

AGCM

Flux Coupler

Land-Surface Model　　　　**OGCM**　　　　**Sea-Ice Model**
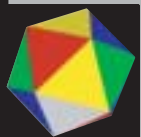
The flux coupler is "the boss."

Framework

We started with a blank piece of paper.

- All model components use geodesic grids.

- Atmosphere and ocean both use quasi-Lagrangian vertical coordinates.

- Parallel flux coupler takes advantage of similar grids.

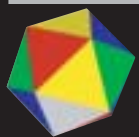- Physical parameterizations are tailored to work with the numerical framework.

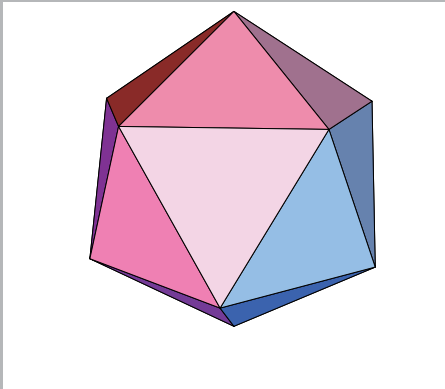*All components are home-grown.*

Geodesic grid(s)
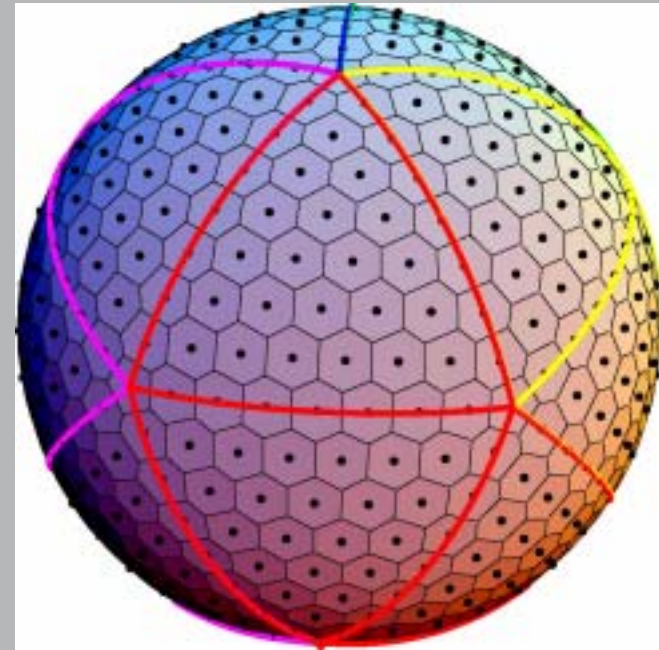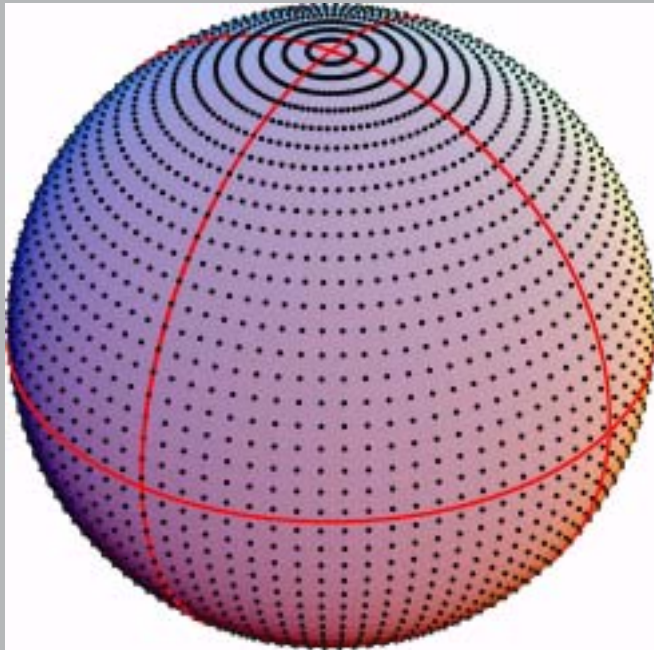
All cells are nearly the same size.
The grid is quasi-isotropic.
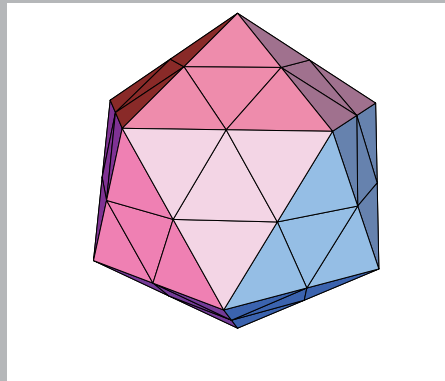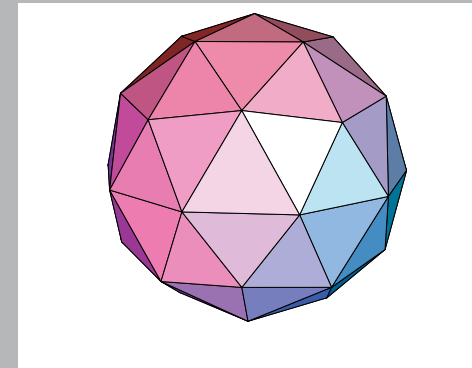Advective CFL is not much of an issue.
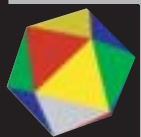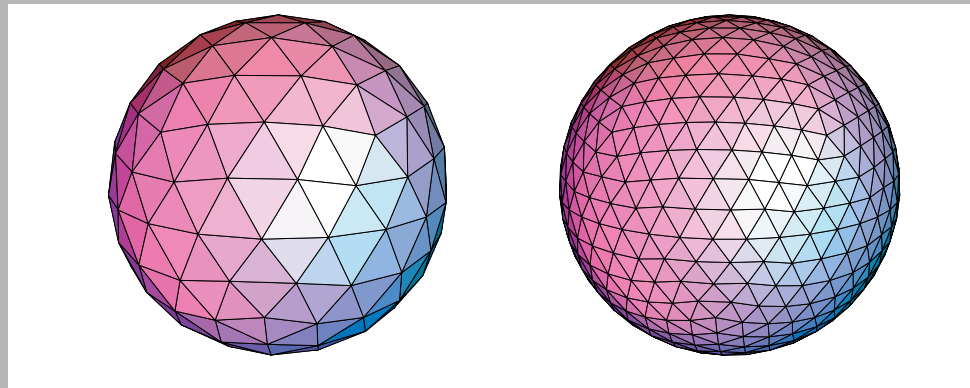
Generating the grid

Icosahedron

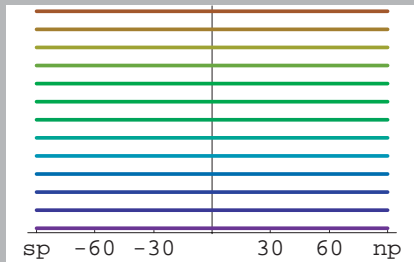**Bisect each edge and connect the dots**

Pop out onto the unit sphere

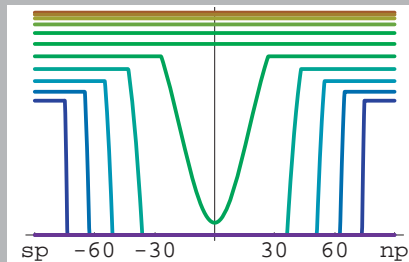**.... and so on, until we reach our target resolution.**

Quasi-Lagrangian Vertical Coordinates

sigma

Lower boundary is a coordinate surface.
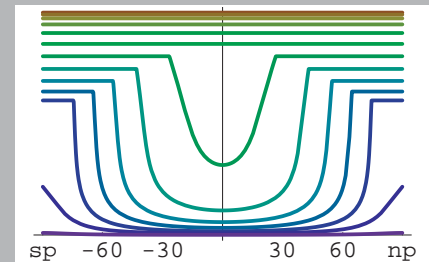
Mass flows freely across layer edges.

theta

Lower boundary is *not* a coordinate surface.

Mass stays within layers except due to heating.

Cannot represent static instability.

zeta
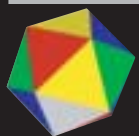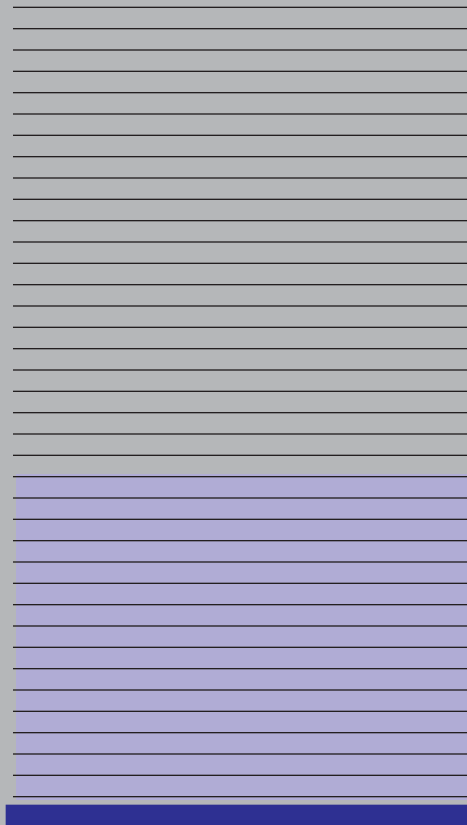
Lower boundary is a coordinate surface.

Becomes theta smoothly and naturally.

Automatically reverts to sigma in statically unstable layers.

Embedded boundary layer
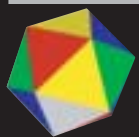
Implicit PBL top
Implicit entrainment

Explicit PBL top
Explicit entrainment

**Zeta coordinate
starts here**

**Thin layers
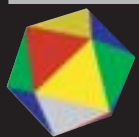Short time step**
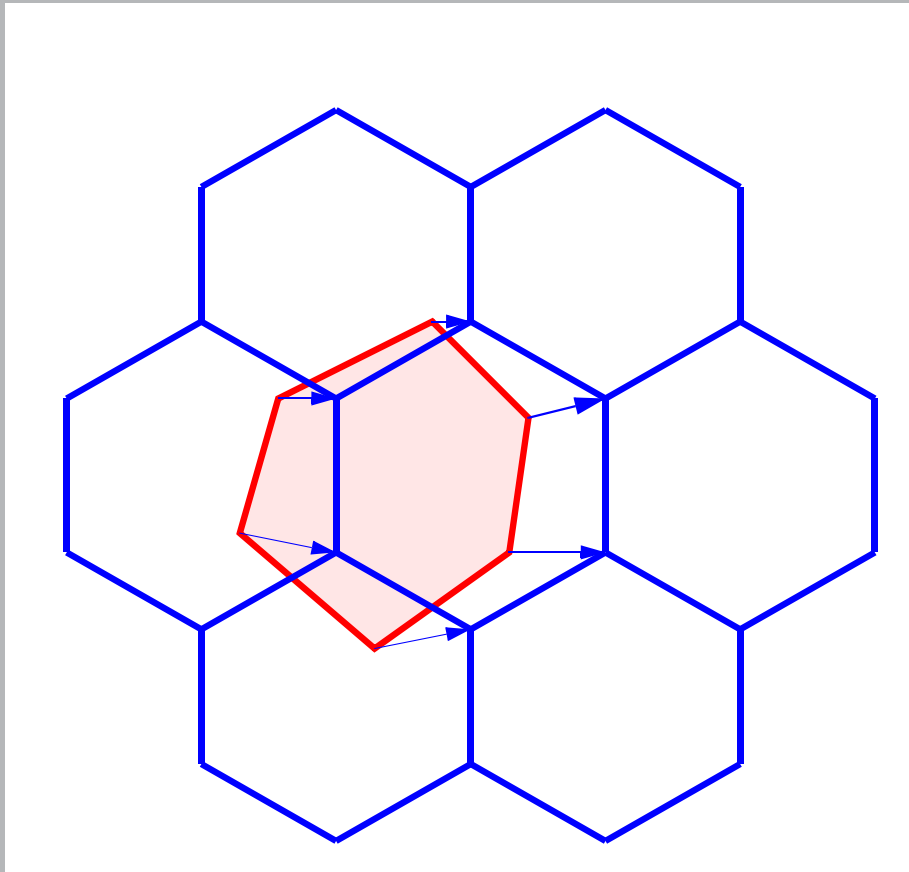
**Thick layers
Long time step**

Mass exchanges across the PBL top
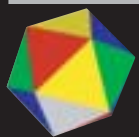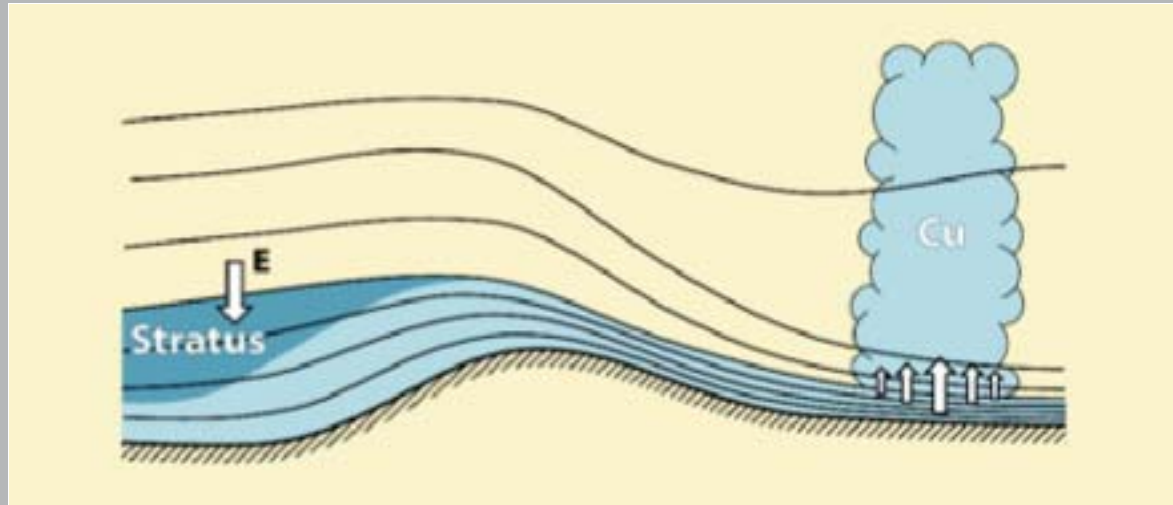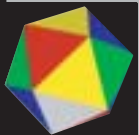
Clouds and stuff
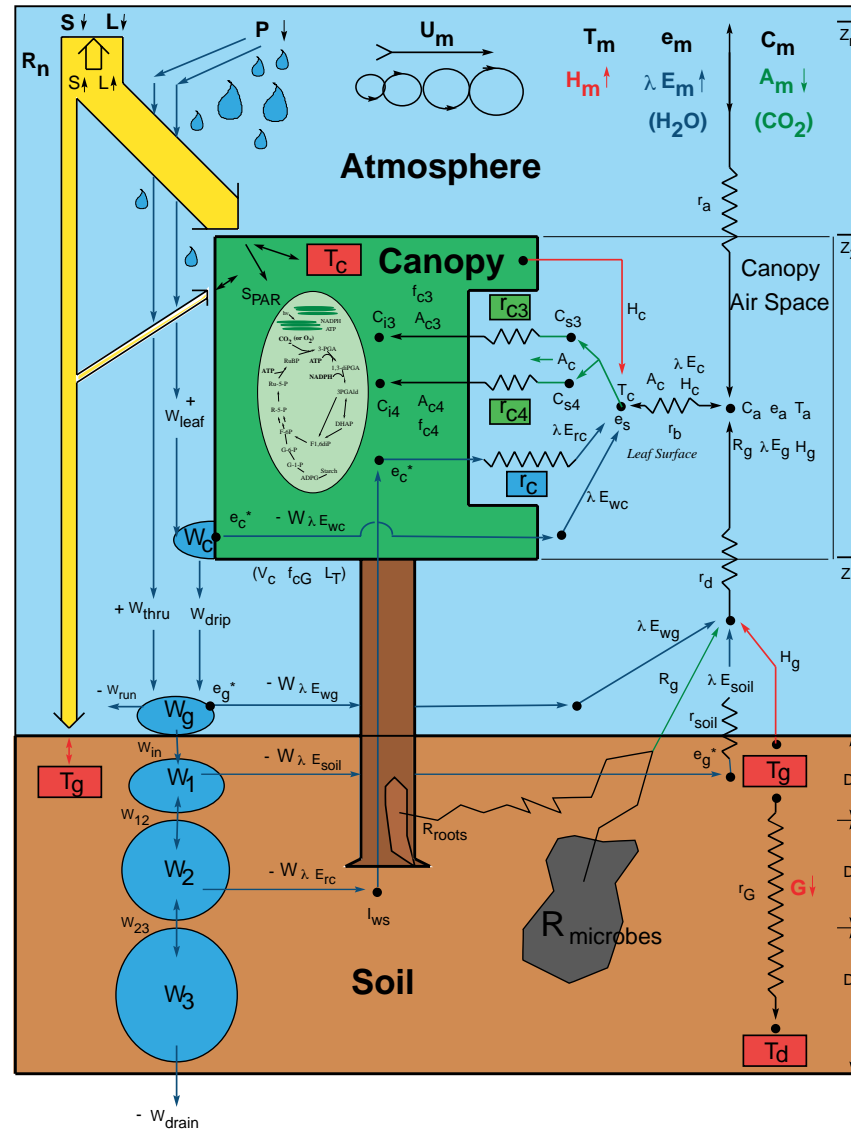
Ocean and sea-ice models

In the sea ice model, transport is represented with a remapping algorithm.

The same approach will be tested in the ocean model.

Land-surface model

Flux coupler

The atmosphere is represented on a coarse geodesic grid, while the ocean and land-surface are represented on a finer geodesic grid.
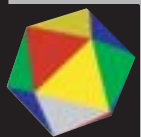
Exchanges of energy, mass, and momentum are computed on the fine grid.

The atmospheric state is "interpolated down," and the fluxes are "averaged up," using methods developed by Phil Jones of LANL.
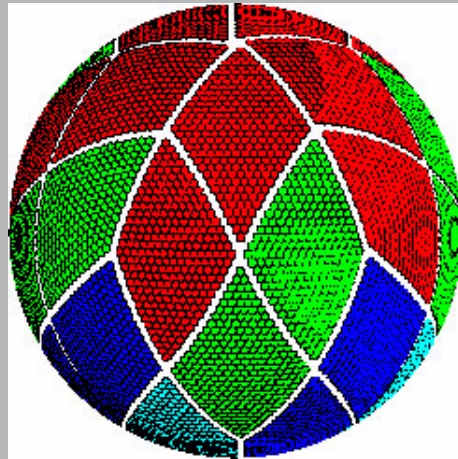
We are not interested in coupling all possible grids to all possible grids.

We are taking advantage of the compatibility of our surface and atmosphere grids.
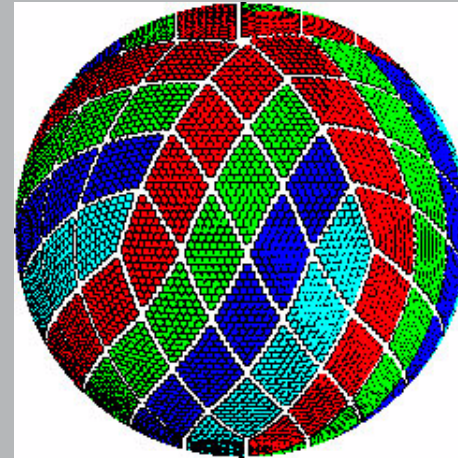
Parallelization with MPI
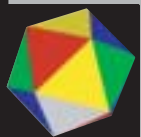
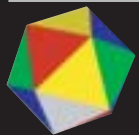Two-dimensional data decomposition works like this:

40 panels   *160 panels*

Each color corresponds to a processor. In this simplified example there are only four processors.

Animation

Status

- **The generalized coordinate is being tested in the atmosphere model.**

    The AGCM is nearing completion.

- **The sea ice model and land-surface model are well along.**

    These are closely related to the corresponding components of the CCSM.

- **The ocean model is lagging somewhat but we are pushing on this now.**

    Major progress is expected this year.